Resource Action: EWG - 31 **Task Force Recommendation Category: 1**

Warm Water Species Habitat Enhancement in Lake Oroville

Date of Field Evaluation: N/A

Evaluation Team: Eric See and Troy Baker with input from Woody Elliott

Description of Potential Resource Action:
This Resource Action is designed to increase and/or improve the structural complexity of the Lake Oroville fluctuation zone to benefit warm water game fish such as black bass and channel catfish that use these areas for spawning and rearing. This would be accomplished by constructing artificial reefs using boulders, weighted pipes, riprap, Christmas trees, logs and other large woody debris, and by planting flood tolerant vegetation such as willow trees, button bush, and cattails, as well as possibly planting annual grasses during the drawdown period. Department of Water Resources (DWR) has been involved in a similar program continuously since 1993, and several other projects were periodically conducted prior to this time. This project would be implemented using an "adaptive management" approach, and would occur in 5-year phases. This Resource Action describes the first 5-year phase.

The following resource actions are either similar to or directly related to the proposed measure:

- EWG-50, that is aimed at maintaining the coldwater fishery in Lake Oroville.
- EWG-68B, that is aimed at building the riparian habitat in the Lake Oroville fluctuation zone.
- EWG-26, that is aimed at improving habitat in a similar manner in Thermalito Afterbay.
- EWG-28, manage water levels in the Thermalito Afterbay aimed at protecting nesting and rearing warm water species (i.e., bass).

Nexus to Project:
- Water level fluctuations hinder the establishment of rooted aquatic vegetation, which reduces cover for game fish and may lead to reduced year-class strength.
- The existing Vegetation Retention Areas, which provide large woody debris habitat for the Lake Oroville fishery, have degraded over time and are in need of maintenance and/or replacement.
- The Department of Parks and Recreation (DPR) has requested the removal of existing tire-reef fish habitat because of concerns regarding mosquito breeding habitat.

Potential Environmental Benefits:
- The primary intended benefit is increasing the habitat complexity in Lake Oroville. This increases the amount of escape cover for juvenile game fish and will reduce the

rate of predation, which can result in increased year-class strength. In addition, the total amount of surface area for periphyton attachment is increased which may increase levels of productivity, benefiting both juvenile game fish, and forage fish production which can also enhance adult warm water and coldwater game fish populations.

- Black bass prefer nesting near macrocover such as rocks, stumps, sunken trees and other large woody debris, submerged brush, etc.
- Brush shelters and mature trees reduce the erosive effects of wave action, decreasing impacts on game fish nests, as well as reducing reservoir turbidity in the habitat enhancement areas.
- Aquatic and terrestrial wildlife (e.g., amphibians, reptiles, birds) also derive benefits from an increase in the structural complexity of the fluctuation zone through increased cover and foraging.
- Reduced mosquito breeding habitat – This Resource Action may include replacing existing tire reef fish habitat with structures that do not have the same water retaining characteristics, thereby reducing mosquito breeding habitat at Lake Oroville.
- Enhanced aesthetics by increasing the amount of trees in the reservoir fluctuation zone, as well as annual grasses if deemed feasible
- These projects are very well received by the local public and generate a significant amount of positive public relations for DWR

Potential Constraints:
Potential constraints associated with this Resource Action could include:

- Navigational/swimming hazards
- Aesthetic concerns with certain materials (e.g., reefs made of used tires considered unsightly)
- Site location (some of the better sites may be located in remote-access areas that are logistically difficult and more costly)
- The extent and duration of water level fluctuations will affect the survival of rooted vegetation and thus limit the areas where they can be planted

Existing Conditions in the Proposed Resource Action Implementation Area:
Lake Oroville is a large two-story (both warm water and coldwater fisheries) reservoir with 167 miles of shoreline at its full pool elevation of 901 ft, with a surface acreage of 15,810. The reservoir can fluctuate more than 100 feet during the course of a “normal" year, with about 250 feet being the most it has ever fluctuated. Annually, the lowest levels occur in the fall, the highest in late spring. These large water level fluctuations, in addition to the reservoir’s steep slopes and poor soils, hinders the establishment of rooted aquatic vegetation in the littoral zone, and restricts the encroachment of terrestrial vegetation into this area (Figure 1). The loss of this cover, which provides spawning and nursery habitat for warm water fishes, is related to observed declines in standing crops of centrarchid species (e.g., black bass, sunfish) as a result of reduced food availability and higher predation on young-of-year fishes (Brouha and Von Geldern 1979).

When Lake Oroville was constructed, the vegetation was removed from the hillsides that were to become inundated, except for selected areas referred to as “Vegetation Retention Areas” (Figure 2). In these areas, large woody debris such as trees and logs were left to provide macrocover for reservoir fisheries. Eighteen areas were designated totaling over 1100 acres. These areas have degraded over time, due to wood decaying processes, along with wave action, water fluctuations, and the rusting of many of the anchor cables used for the log structures.

Although centrarchid cover is limited at Lake Oroville, centrarchid spawning substrates such as clay, sand, and small gravel are relatively abundant so substrate enhancement is unnecessary for these species. However, this is not the case with channel catfish spawning habitat. Channel catfish prefer to spawn in ”cave-like” sites in undercut banks, large root wads, log jams, under large rocks, and other protected sites. Although the extent has not been documented, the degradation of the Vegetation Retention Areas has resulted in the loss of some of this habitat.

During the 1980s, the Department of Fish and Game (DFG) and DPR, along with several fishing organizations, constructed reefs made of discarded tires in several coves around Lake Oroville (Figure 3). Although these reefs are an effective, durable, and inexpensive type of fish habitat, providing habitat for centrarchids as well as channel catfish, they also have a tendency to retain water when the lake recedes, which provides suitable habitat for mosquito breeding. DPR has requested that these reefs be replaced with fish habitat that will not create the same problem, such as large woody debris, brush shelters, and willow trees.

Design Considerations and Evaluation:

This Resource Action involves 3 different types of habitat enhancement projects, brush shelters, flood tolerant trees and annual grasses (if deemed feasible), and channel catfish spawning structures.

<u>Brush shelters</u>
Brush shelters are reefs that are constructed on the lakebed within the reservoir fluctuation zone (Figures 4 and 5). They consist of various materials including discarded Christmas trees, trees/brush cut from the upland areas adjacent to/near Lake Oroville, and artificial habitat structures made of plastic. The brush shelters are anchored to the lakebed using steel fence posts, concrete blocks, or other suitable materials, to keep the brush shelters from floating away when inundated during the spring and summer. Typically brush shelters are built as separate units covering 150 to 400 ft^2 of lakebed, and they are installed in clusters in the back of coves with shallow sloping banks. These are common spawning areas for black bass, particularly largemouth bass, so these brush shelters would be located to increase spawning success (nest protection from wave action, satisfy bass preference for spawning near structure), as well as increase post-spawn survival of juvenile bass. Projects should be targeted in the elevation range between 775’ to 875’ to provide spawning benefits at a variety of ranges, and because during the summer and

fall, young bass inhabit a zone down to a depth of about 25', so enhancement projects conducted in this range will provide benefits to bass when lake levels are in the range of about 800' to 900'. An evaluation of site specific conditions such as slope, soil type, exposure, access, and other factors (cultural resources, existing trees, geologic formations, etc.) will determine the specific placement and types of structures. Current locations identified (others may be identified):

- Cove near the Spillway (Christmas trees)
- Parrish Cove (Christmas trees, and/or cut trees and brush)
- Miners Ranch Area of Bidwell Cove (Christmas trees, and/or cut trees and brush, and/or artificial structures)
- Vinton Gulch (Christmas trees)
- Near Loafer Creek Group Campground (Christmas trees, and/or cut trees and brush, and/or artificial structures)
- Coves near Foreman Creek Boat-in Campground (Christmas trees, and/or cut trees and brush, and/or artificial structures)
- Cove south of State Service Ramp, across from Loafer Creek Picnic Area

Construction of brush shelters would be implemented on an annual basis, and the target amount would be the equivalent of approximately eighty 10'x20'x3' brush shelters, which would enhance approximately 2 acres of lakebed. It is difficult to assign specific sizes and amounts with brush shelter projects because they differ so much in their design based upon the materials used and the conditions at the site. However this target should provide an approximate annual goal for these projects.

These projects are very popular with the local public. Many different local groups have volunteered to assist DWR in its current brush shelter activities, including the Boy Scouts of America, local fishing clubs, schools, and private citizens. This Resource Action will continue this tradition of working with the public on these projects, and the extent of the projects in a given year may be expanded based upon the level of local volunteer involvement.

Flood Tolerant Trees

Native trees such as willow (*Salix spp*. and buttonbush (*Cephalanthus occidentalis*) would be planted in the fluctuation zone in the 850'–890' elevation range. These trees can survive periodic inundation as well as dry conditions found in the fluctuation zone in during the summer and fall, particularly if they survive the first 1 or 2 years and establish a deep root system. When successfully established, these trees provide large amounts of structural complexity over a long period of time and have the added benefit of enhancing the aesthetics of the reservoir fluctuation zone (Figure 6). As an example, many of the willows planted by DFG during the 1970's are now over 20' high and continue to grow, increasing the amount of cover provided. The 850' elevation is the lowest these trees should be planted because any planted below this elevation stand the possibility of being inundated year-round on a wet year due to the flood storage operations at the lake. This is why very few trees have ever survived long term at lake Oroville below this elevation, and even those trees are not found lower than about 840'.

The trees planted would primarily come from cuttings taken from existing trees in the fluctuation zone of Lake Oroville, because they are located close by, and are species that have proven abilities to survive in the harsh environment of the reservoir fluctuation zone. Two types of planting techniques would be used, planting unrooted cuttings, and planting rooted cuttings. Unrooted cuttings, or slips, would be cut and planted directly in the lake bed prior to the slips drying out. With rooted cuttings, the cuttings are planted in a nursery and grown for a period of time, typically a year, and then transported to the lake for planting in the fluctuation zone. Rooted cutting are more expensive, however they have a higher chance of survival (approximately 5%-15% survival) than slips (approximately 1%). This Resource Action would utilize both techniques.

One of the most important factors for success in establishing flood tolerant trees in the fluctuation zone is survival during the first 1-2 years after planting, and this is usually related to lack of soil moisture. Most of the fluctuation zone is lacking in summertime water sources (streams, springs) in areas that are ideal for warm water fish habitat enhancement (back of coves, shallower slope, 850' – 890' range). In addition, this zone is subjected to several months of very hot and dry conditions from mid-July through mid-October, and it is during this time that most newly planted trees will not survive. Under these conditions, Lee and Gleason (1989) recommend developing an irrigation plan prior to planting, and this would be a significant component of this habitat enhancement activity. Irrigation techniques could entail pumping water to the trees from Lake Oroville or tributaries (or diversions in the case of tributaries), piping water from developed water sources at campgrounds and picnic areas, pumping water from existing flumes (Figure 7) along the shoreline such as the Miocene Canal in the Lime Saddle Area, and the Oroville Wyandotte Irrigation District (OWID) canal on the South Fork Arm, or trucking water to the enhancement areas. Drip systems would be constructed to deliver the water to the trees most efficiently, either tapping directly into a developed system, or installing water tanks at the top of the system. Based on previous experience at Lake Oroville, and depending upon the specific site conditions of slope, soil type, exposure, and access, a target range of 300 to 500 trees per acre should be used. The trees would be watered once every 10 days, and would average about 1 gallon per tree per day for a range of 2700 to 4500 gallons (less than .015 acre-feet) of water per acre annually.

Current locations identified for construction of these systems (others may be identified):

- Cove near the Spillway Boat Ramp (tap into existing developed water system)
- Near Bidwell Campground (tap into existing and possible future developed water system)
- Near Loafer Creek Group Campground (tap into existing developed water system)
- Miners Ranch Area (divert existing creek)
- Parrish Cove (tap into existing developed water system from campground and/or Lime Saddle Boat Ramp, or pump from Miocene Canal)
- ~12 coves along 7 miles of the South Fk. Arm (pump water from OWID canal located immediately above the high water mark of Lake Oroville, as shown in Figure 6)
- Cove south of State Service Ramp, across from Loafer Creek Picnic Area

An enhancement area with a minimum of 1 acre would be needed to justify the cost for each of these systems, and a cost-benefit analysis would be conducted for each location. Rooted trees would primarily be used with irrigation systems because of their increased chance of survival improving the cost-benefit ratio. One irrigation system per year would b constructed, and approximately 1000 trees would be planted.

In addition to planting rooted trees in irrigated areas, slips would be planted in large quantities in various locations. A 10-person work crew is capable of cutting and planting several thousand cuttings per day, so although survival is much lower, this method will result in at least some survival at a lower cost (~60%-80%). Approximately 10,000 slips would be planted on an annual basis.

Current locations for willow and button bush slip planting (others may be identified):

- Nelson Bar Area
- Miners Ranch Area
- South Fork Arm
- Foreman Creek Area
- Near Loafer Creek Group Campground
- Parrish Cove
- Vinton Gulch
- Cove south of State Service Ramp, across from Loafer Creek Picnic Area

Annual grasses that germinate in the fall and grow during the winter could be planted to provide microcover for juvenile fish (Lee and Gleason 1989; Strange et al. 1982). These include Wimmera #C2 ryegrass, *Lolium rigidum*; lana vetch, *Vicia dasycarpa*; and Blando brome, *bromus mollis*; and/or others, could be planted in small 1-5 acre areas with hand spreaders, or in larger areas (20-50 acres) by airplane. Use of fertilizers and disking may be conducted to increase success. This project would need to be reviewed for its potential impacts on native grasses in the Lake Oroville area. A similar project has been discussed in the Land Use Workgroup as an enhancement to the barren fluctuation zone for aesthetic purposes, so these projects could be combined if desirable.

Possible locations for grass seeding (others may be identified):

- Cove near Spillway Boat Ramp
- Potter Ravine
- Foreman Creek Area
- Loafer Creek Area

<u>Channel Catfish Spawning Structures</u>

As previously mentioned, channel catfish prefer to spawn in secluded,”cave-like” locations. This project would primarily involve the placement of 3-4 ft. sections of 9-18 in. diameter concrete and PVC pipe, which makes excellent spawning habitat. Other materials may be substituted for concrete and PVC pipe based on availability, including scrap pieces of culvert, steel pipe, buckets, and other discarded items found around the Oroville Field Division. Rock rubble and other materials that create similar cavities may

also be used. These “pipe-caves” would be placed in the same areas and elevations identified for brush shelters, as well as several of the coves along the South Fork Arm, which is the most popular channel catfish fishing area at Lake Oroville. Due to the territorial behavior of male channel catfish during the spawning season, the pipe-caves would be placed at least 40 ft. apart to reduce fighting among males (Lee and Gleason, 1989). In order to prevent the creation of mosquito breeding habitat, all of the pipe-caves would be installed in a manner that did not result in standing water as the lake is drawn down, as currently happens with the tire-reefs. The pipe would be oriented for the water to drain out and/or holes could be drilled for additional drainage.

A target of 100 3-4 ft. pipe-caves would be installed each year, which would cover approximately 4 acres of lakebed.

Rock Reefs

Reefs made of boulders, rip rap, or other rubble material could be constructed to increase the amount of structure in the fluctuation zone. These reefs would be located in the same areas identified for brush shelters, and would be designed to provide the maximum amount of surface area and interstitial spaces for juvenile black bass cover, as well as “cavelike” channel catfish spawning habitat. These reefs are very long lasting, and do not have the brush shelter potential of breaking apart and floating away. The high cost of transport of these rubble materials would be a limiting factor in their use, however this project will be considered as an alternative to brush shelters if “waste” rubble becomes available in the local area.

Project Summary

The following is a summary of the projects in this Resource Action, they would be implemented annually over a 5-year period, at that time an evaluation for continuing this Resource Action for another 5 years would be considered along with potential alterations. These are estimates and may vary ±15%)

80 brush shelters
1000 rooted willow and/or buttonbush trees
10,000 willow and/or buttonbush slips
1 Irrigation System
Planting of Annual Grasses (needs to be coordinated with other Resource Actions)
100 Channel Catfish Spawning Structures
Construction of rock reefs if waste material can be acquired (number of reefs will be based on amount of available material, total would be similar to that of brush shelters)

Environmental permitting requirements may include:

CEQA

DFG 1601
ACOE 404
CWA 401

A monitoring program of the effects on the fishery could include springtime snorkel surveys and/or electrofishing to assess fish species composition, abundance, and size structure in the habitat enhancement areas. This would be used to confirm utilization of these projects by the target fish species such as black bass and channel catfish, and better hone the planning and implementation of future projects (brush shelter design, pipe-cave design, site location, etc.) Fish population monitoring could also be conducted to identify the overall effect on the fish production, however these analyses require a much higher level of effort and are more expensive, possibly exceeding the cost of the enhancement projects. This monitoring could be incorporated into Lake Oroville fishery monitoring for other Resource Actions or studies by other agencies.
Monitoring the projects themselves would involve recording the date of implementation and location of the projects (structures, grasses, trees, etc.) and then checking them over time. Periodic revisions in structure design may be necessary to increase their durability and/or effectiveness. Survival of willow trees and amounts of annual grasses would be recorded to monitor success in the various areas and this information will be used to identify better methods and sites for future plantings.

Synergism and Conflicts:

Synergism and Conflicts:

Synergisms could be created if this measure is planned in conjunction with other Resource Actions designed to enhance habitat for warm water species in Lake Oroville. This could include EWG-68B, which is aimed at building riparian habitat in the Lake Oroville fluctuation zone. EWG-68B could benefit warm water species nesting or rearing along the Lake Oroville shoreline. An additional measure related to this action is the proposal to plant willow trees in the Lake Oroville viewshed. Planting willow trees in Vegetation Retention Areas could result in a synergism with this measure. Riparian plantings would add structural complexity in the Lake Oroville fluctuation zone and thus provide a habitat benefit for warm water species. Concerns have been raised about the persistence of mosquito breeding habitat in tire-reefs because standing water is present after drawdown occurs. This measure is related to a resource action currently being considered by the Land Use, Land Management, and Aesthetics Workgroup designed to create an integrated, site-specific approach to pest management (LWG-6). Replacement of these tire-reefs with large woody debris and properly drained pipe-caves would reduce this mosquito habitat, thereby assisting with pest management. This Resource Action is synergistic with the development of a recreational fishery management plan since it would primarily benefit the Lake Oroville recreational fishery.

A conflict could occur with activities designed to eliminate noxious plants in the Lake Oroville fluctuation zone (EWG-74B). Vegetation growth in the fluctuation zone adds temporary structural complexity to lake substrates following inundation. Elimination of

noxious vegetation in the fluctuation zone during dewatered periods would result in a net decrease in available rooted vegetation and thus limit habitat complexity when lake levels have risen. In addition, because these projects are designed to increase the amount of structure in the fluctuation zone, a certain amount of navigation and swimming hazards may be created. This would be kept in mind when determining the location and design of the structures to be installed; certain projects (e.g., brush shelters, rock rubble) may not be implemented near swimming areas or high boat traffic areas of the lake. Warning buoys and/or signs would be considered. Due to the location and nature of these projects, impacts to cultural resources may occur so consideration of this would be an integral component of the planning. These projects are flexible enough in their design and location options to allow avoidance of cultural resource impacts, and may even be able to assist in the protection of these resources by concealment of the resources themselves and/or construction of barriers to reduce vandalism and vehicular impacts (e.g. boulder installation). All of these projects will go through a formal archaeological review prior to implementation.

Uncertainties:

The main uncertainty associated with this Resource Action would be determining the level of success of the various projects. Monitoring may indicate increased fish utilization of these areas, however it will be difficult to determine if this is related to increased production, or a result of fish being attracted to these areas. In addition, the fluctuation regime, water temperatures, weather patterns, and many other environmental factors that are difficult to quantify may affect the numbers of fish in a given year and mask the impact of this Resource Action. Site locations may need to be changed based upon issues raised in the environmental permitting process, such as sensitive cultural resources.

Cost Estimate (Annual):
80 brush shelters: $23,000
1000 rooted willow and/or buttonbush trees: $1500
10,000 willow and/or buttonbush slips: $3000
1 Irrigation System (includes O&M): $3000
Planting of Annual Grasses (tentative): $500 – $5000?
100 Channel Catfish Spawning Structures: $3500
Monitoring: $3000 - ?
Rock Rubble: $10,000
Annual Total: $35,000 – $50,000 (with review after 5 years)

Recommendations:

This Resource Action has been reclassified as a Category 1, and should be considered as an alternative for mitigating the potential negative effects of project operations on warm water game fish at Lake Oroville. These projects are designed to strengthen year classes of centrarchid and ictalurid species in Lake Oroville which are very popular gamefish. Along with fishery benefits, these projects can enhance the aesthetic aspects

of the reservoir fluctuation zone, as well as provide benefits for terrestrial species by increasing the structural complexity in these areas. In addition, these projects are well regarded by the local public and provide the opportunity for outreach programs with local organizations such as the Boy Scouts of America, fishing organizations, and area schools.

Literature Cited:

Brouha, P. and C.E. Von Geldern. 1979. Habitat manipulation for centrarchid production in western reservoirs. pp. 11-17 *in* D.L. Johnson and R.A. Stein, editors. Response of fish to habitat structure in standing water. North Central Division American Fisheries Society Special Publication 6.

Lee, D.P. and E. Gleason. 1989. Warmwater reservoir fish habitat improvement techniques. California Department of Fish and Game, Inland Fisheries Informational Leaflet, Number 42. 29 pp.

Strange, J.S., Kittrell, W.B., and T. Broadbent. 1982. Effects of seeding reservoir fluctuation zones on young-of-year black bass and associated species. North American Journal of Fisheries Management, Volume 2, Number 4, pp. 307-315.

Figure 1. Lake Oroville Fluctuation Zone (Spillway Cove)

Figure 2 Vegetation Retention Area (McCabe Cove)

Figure 3. Tire Reefs (Miners Ranch Area)

Figure 4. Christmas Tree Brush Shelters (Miners Ranch)

Figure 5. Manzanita Brush Shelter (Spillway Cove)

Figure 6. Willow Trees (Miners Ranch Area)

Figure 7. O.W.I.D. Canal (South Fork Arm)

Resource Action: EWG-98 **Task Force Recommendation Category:** 2

Proposed Creation or Enhancement of Salmonid Spawning and Rearing Habitat in the Tributaries of the Lower Feather River

Date of Field Evaluation: September 16, October 29 and November 6, 2003

Evaluation Team: Brad Cavallo, Koll Buer, Eric See, Jason Kindopp, Richard Harris, Bruce Ross, and Michael Manwaring

Description of Potential Resource Action Measure:

The goal of this Resource Action is to create or enhance salmonid spawning and rearing habitat in tributaries of the lower Feather River. This habitat would supplement existing habitat in the main stem and partially replace upstream habitat that was lost when Oroville Dam was constructed. Depending on the site involved, implementation of this measure may require habitat construction or restoration and/or provision of year-round water supplies. Water supplies could be derived from project waters or other sources and delivered to tributaries by construction or extension of diversions, channels, or conduits.

At the present time, it appears that tributaries downstream from Oroville Dam (exclusive of the Yuba and Bear Rivers) are not utilized for spawning or rearing by anadromous salmonids.

Potential sites for spawning and rearing habitat creation/enhancement were evaluated as part of several field trips conducted on September 16, October 29 and November 6, 2003 with DWR, Butte County, and consultant staff. Potential sites investigated included: North Honcut Creek, South Honcut Creek, Wilson Creek, Ruddy Creek, an unnamed creek that is located near Highway 70, and an unnamed channel located near the hatchery.

There are several other Resource Actions that are either similar to or otherwise related to this measure:

- EWG-13A/20 and EWG-13B that propose to improve rearing habitat through placement of wood and other materials in the low flow reach and lower Feather River.
- EWG-16A and EWG-16B, that propose to create or enhance side channel habitat in the low flow reach.
- EWG-99, which would involve creating or enhancing side channel habitats in the lower Feather River.

Nexus to the Project:
Many factors, including flood control levees, construction of the dam at Lake Oroville, historic land use activities (hydraulic mining), and regulation of stream flows have caused changes to geomorphology and substrate in the Feather River system. The cumulative impacts of these changes have generally reduced the availability (quantity and quality) of spawning and rearing habitat for anadromous fishes. Replacement of habitat lost or degraded due to the construction of the dam would improve the productivity of the anadromous salmonid fishery.

Potential Environmental Benefits:
The most immediate potential benefit of the proposed Resource Action would be an increase in the available spawning and rearing habitat for Central Valley steelhead and Chinook salmon, specifically Central Valley spring-run Chinook salmon, both threatened species under the Endangered Species Act. Ultimately, improvements in habitat should result in improved fish production and escapement.

Potential Constraints:
Constraints on this measure are both general and site-specific. An overriding constraint is availability of funding to carry out major stream habitat restoration projects in tributaries. None of the sites investigated currently has especially favorable habitat conditions for spawning or rearing. Consequently, a variety of physical habitat improvements would be necessary at any of the sites.

A second general constraint is the availability of water. Except from the site near the Hatchery, none of the additional locations investigated currently has a reliable source of year-round water that is of suitable quality for anadromous fish production. The quantity and quality constraints vary by site.

Other site-specific constraints are discussed in the evaluations below.

Existing Conditions in the Proposed Resource Action Implementation Area:
It is generally understood that availability of spawning and rearing habitat are limiting factors for production of steelhead and, perhaps, spring-run Chinook salmon in the Feather River below Oroville Dam. The construction of the dam precluded passage of fish to the upper Feather River where favorable habitat conditions were historically present for steelhead and spring Chinook. Therefore, the intention of this measure is to provide replacement habitat in tributaries below Oroville Dam. With the exception of the Yuba and Bear Rivers, there are few such tributaries. The major tributary is Honcut Creek. Consequently, the main focus of this investigation was on Honcut Creek. However, some additional tributaries were identified and evaluated as well.

Honcut Creek: For the purposes of this Resource Action, North Honcut Creek, South Honcut Creek, and Wilson Creek were investigated to evaluate their potential for habitat creation and/or enhancement. Ten sites along the three streams were evaluated (including one stop at Natchez Creek, a tributary to South Honcut Creek).

It should be noted that at the present time, there is no evidence available that indicates any significant usage of the Honcut Creek system by anadromous salmonids.

One important issue that was not addressed for Honcut Creek was fish passage. Neither access, nor time available to conduct this study allowed evaluation of whether or not fish would be able to navigate Honcut Creek or its tributaries. Passage barriers could include diversion dams (one was observed in the upper watershed), culverts or bridges or high gradient stream sections. There does not appear to be any barrier present at the confluence of Honcut Creek with the Feather River.

With respect to the availability of water in Honcut Creek and its tributaries, at the present time, South Feather Water & Power (formerly Oroville-Wyandotte Irrigation District) owns water rights and diverts some level of flow (presently unknown) from Honcut Creek to the South Fork of the Feather River. Other appropriated rights undoubtedly also exist in the downstream reaches. Riparian rights are utilized by landowners throughout the watershed. In addition, wells in near-stream alluvial deposits were observed during the site visits. There is also not presently a reliable source of year-round water supply for instream uses at Honcut Creek.

At the ten sites in the watershed that were observed in the field, several conditions were noted:

- Stream water temperature,
- Stream flow
- Channel substrate
- Riparian vegetation
- Habitat types
- Stream gradient
- Water quality

In the upper watershed, there were reaches of stream with somewhat favorable habitat conditions. That is, they had appropriate habitat types (pools, side channels, and riffles), good riparian cover and at least some spawning gravels. However, low streamflow and attendant high water temperatures were ubiquitous. Also, predatory pikeminnow were frequently observed. Habitat conditions deteriorate with distance downstream. Aggradation with fine sediment has impacted the lower reaches, obliterating pool-riffle sequences. Streamside riparian cover is discontinuous. Water quality visibly declines and water temperatures increase.

In summary, the Honcut Creek system appears to be seriously limited as a potential site for creation or enhancement of anadromous salmonid habitat. The main constraints are (potentially) passage, water availability, habitat quality, presence of predatory species and water quality (temperature and nutrients, primarily). There may be additional

constraints associated with the prevalence of private land in the watershed and willingness of landowners to engage in restoration efforts.

Other Tributaries. For the remainder of the tributaries evaluated, the following site characteristics were examined:

- Site length and/or area
- Site connectivity to the Feather River
- Instream habitat quality
- Riparian habitat quality
- Proximity of site to spawning habitat
- Existing streamflow
- Streamflow requirements

On the basis of field observations by all participants, the specific constraints and opportunities related to salmonid habitat restoration and enhancement at each site were discussed. At all sites evaluated, additional information would be required to develop a concept for implementation.

> **Ruddy Creek:** Prior to the construction of the Oroville project, Ruddy Creek traversed the present location of the Thermalito complex. Its former headwaters were in the Table Mountain area. Pre-Oroville project topographic maps (1952) indicate that it was then an intermittent stream terminating in a dredger tailings pond. At the present time, it exists as three separate channels originating at the base of the Forebay. From there, the channels eventually merge into a single channel that presently has its terminus at a pond in the Oroville Wildlife Area.
>
> There is no historical evidence indicating that Ruddy Creek ever provided habitat for anadromous salmonids.
>
> Ruddy Creek is approximately 4 miles long. FEMA floodplain maps indicate that it has a substantial 100-year floodplain below Thermalito. At the present time, it is not directly connected to the Feather River. It may connect when flooding of its terminal pond coincides with high flows in the Feather River (>10,000 cfs). Instream habitat quality is generally poor. Channel conditions vary in a downstream direction. At its origin, the three branches are essentially wetlands with little channel definition. Further downstream, in the vicinity of Tehama Street, it is an open ditch that has been recently cleared. In the vicinity of Biggs Street, it is a grassy channel. Overall, except perhaps for the Oroville Wildlife Area, the stream has no current value as habitat for anadromous or other fish. Riparian habitat quality is equally limited. In the upstream area, except immediately downstream from the Forebay, the riparian zone is essentially absent. Further downstream, there is some riparian cover, but most of it consists of exotic species such as annual grasses, eucalyptus and giant reed. In the Oroville Wildlife Area, riparian cover is of higher quality, consisting of cottonwood and

other native (as well as exotic) species. There was some water in the stream during field observations. The sources for streamflow are seepage from the Forebay (toe drains discharge directly to the Ruddy Creek channels), local runoff and return flows from developed or agricultural areas and perhaps, groundwater discharge to the stream.

If a project focused on salmonid habitat restoration were to be implemented on Ruddy Creek, there would be at least two major constraints. First, streamflow would be needed. This could be provided with a conveyance facility from the Forebay or in conjunction with a proposal to divert cold water from the Afterbay. It is estimated that re-watering the stream would require about 15-20 cfs. This would be minimum flow and would not account for channel maintenance or scouring flows that might be required. Second, a permanent connection between Ruddy Creek and the Feather River would be needed. There are a few options for doing that. For example, a new channel could be constructed from the present terminus to the Feather River or a connection could be made with a combination of the old Western Canal and Ruddy Creek. In either of these cases, a major geomorphic restoration effort would be needed, including provisions for breaching levees.

Additional factors that limit the suitability of Ruddy Creek as a site for salmonid habitat restoration include its flat gradient, lack of sinuosity and other natural stream channel features, unsuitable substrate, existing and proposed adjacent land uses, water quality and perhaps, barriers associated with road crossings and other obstructions.

If the emphasis on restoration of Ruddy Creek had different objectives than salmonid habitat creation or enhancement, other opportunities arise. For example, if restoration of Ruddy Creek were based on improving aesthetics, flood management and wildlife habitat, there would not be a need to connect with the Feather River. However, re-watering Ruddy Creek may have other impacts that would require further consideration.

An additional alternative would be to focus salmonid habitat restoration in the lower reaches in the Oroville Wildlife Area. In this case, options for water supply should be evaluated. If water were supplied from the Forebay, there would likely be concerns about water losses and temperature (increasing) because of the distance that the water would need to travel.

Unnamed Tributary Near Highway 70. This tributary in the northern portion of the city of Oroville is an open channel from about Grand Avenue, crossing under Highway 70 and apparently terminating at a pond upstream from the Feather River. Although the confluence was not examined in the field, the stream does not appear to be directly connected to the Feather River. It is approximately 0.5 mile in length. It is partly bordered by land that is under development. Instream

habitat quality is relatively poor. Riparian habitat varies, but it is generally dense and dominated by exotic species. The stream would have its confluence in the vicinity of important spawning habitat in the Feather River. At the time of field observations, there was some flow, most likely emanating from urban runoff.

The constraints to creating or enhancing habitat in this tributary would include providing a connection to the Feather River and ensuring an adequate water supply. Instream habitat restoration would be necessary.

Unnamed Tributary Near Hatchery. This field evaluation was not intended to cover the Hatchery Ditch or Moe's Ditch. The potential for enhancing habitat in those channels was evaluated in the report on EWG-16B. The focus of this evaluation was on a channel located at the base of the terrace near the rear of the Hatchery.

The channel may be a secondary channel or former main channel of the Feather River or it may be an artifact of past hydraulic mining. Its location at the base of the terrace suggests it was a Feather River channel, and is about one mile long. It is not presently connected to the Feather River. The upstream end was not visited but apparently terminates upstream from the Hatchery. The downstream end is abruptly terminated by an unculverted road fill. The entire area adjacent to the channel consists of dredge spoils. These have obliterated not only the former floodplain but also the former channel below the road fill and the connection to the Feather River.

(Note: A possible continuation of the channel at the base of the terrace appears on topographic maps but was not visited in the field. On maps, this continuation appears to cross under Highway 70 and join the unnamed tributary, previously described. Further study of this channel may be warranted.)

The channel currently sustains little if any surface flow. There is no channel definition or instream habitat. Riparian vegetation, including both native and exotic species, completely occupies the channel.

There would be opportunities and constraints associated with a habitat improvement project in this channel. It could serve as rearing habitat for steelhead. However, there would have to be a re-connection to the Feather River. This could be achieved by constructing a new channel from the current downstream terminus, across dredge spoils, to the river. This new channel could serve as spawning habitat if it has the proper geomorphology and substrate. The new channel should be reconstructed within the boundaries of state-owned property to avoid conflicts with other landowners. In addition to channel construction and re-connection to the Feather, a major restoration effort would be required within the channel. This would probably entail clearing existing vegetation and use of instream structures. To sustain flows, approximately 20 cfs

would be required, in addition to other flows for channel maintenance. The probable source for this water would be the Hatchery water supply, which consists of approximately 120 cfs. About 40 cfs is available from this source. Half could be used for the new channel and half could be used as a permanent source of water for Hatchery Ditch.

Design Considerations and Evaluation:
The choices for creating and enhancing habitat in downstream tributaries are clearly limited. For any of the potential sites, there are three overarching design considerations:

- Water supply
- Connectivity to the Feather River
- Instream habitat quality

Water Supply. At any site, a permanent source of water supply must be procured before proceeding with detailed restoration planning or design. Although each site has different opportunities for procuring water supply, the two general sources are either project or non-project waters. In the case of the Honcut Creek tributary system, diverting project waters to the headwaters where the most suitable habitats exist would require construction of conveyance facilities. As an alternative, an effort could be made to procure or exchange water rights held by the irrigation district and/or landowners.

It would be relatively easy to provide project waters to Ruddy Creek. Water could be diverted directly from the Forebay to one or more of the channels originating there. There is also a proposal to divert cold water from the Afterbay that could provide water to the downstream reaches of Ruddy Creek.

Although not examined in the field, the Highway 70 tributary appears to have its origin approximately 0.5 mile from the Thermalito Power Canal. However, in that upstream area the stream appears to be at least partially underground. The canal is a potential source of project waters.

Providing water supply to the channel near the Hatchery would require diverting flow that would otherwise service the Hatchery. However, the water supply demands at the Hatchery do not require its total allocation so the water would be available.

Connectivity.
The connectivity of the Honcut Creek system to the Feather River at the confluence appears to be adequate.

Ruddy Creek is not currently connected to the Feather River under normal flow conditions..

The Highway 70 tributary is not connected to the Feather River. It would be possible to construct a new channel across existing dredge tailings to reconnect it. The new channel could provide some spawning habitat.

The channel near the Hatchery is not connected to the Feather River either upstream or downstream. If it were connected downstream, it could provide both spawning and rearing habitat and there would be no need to create an upstream connection. A channel could be constructed from the downstream terminus across the dredge tailings to the Feather River. The newly constructed channel could provide spawning habitat and the existing upper reach could provide rearing habitat.

Instream Habitat. At any site, extensive instream habitat improvements would probably be required. In the Honcut Creek system, the quality of habitat in the downstream reaches is poor. There is good quality habitat in the upper reaches.

None of the other tributaries evaluated has quality instream habitat. Ruddy Creek has virtually no current instream habitat values. The Highway 70 tributary has some instream structure in its upper reach near Grand Avenue. Encroachment by vegetation has eliminated any habitat values that may have been present in the Hatchery channel.

In summary, there are no easy solutions to creating or enhancing habitat for anadromous salmonids in tributaries downstream from Lake Oroville. The concept of enhancement is probably not even relevant. At any site chosen, at least some level of habitat creation would be required.

Synergisms and Conflicts:
Any project to improve conditions on tributaries should be considered within the context of a comprehensive program for improvements to spawning and rearing habitat for anadromous salmonids. In that way, different approaches to achieve the same objectives can be compared and evaluated. For example, there are at least three ways in which spawning and rearing habitat can be increased: 1) changes to the main stem of the Feather; 2) restoring access to upstream tributaries; or 3) treatments to tributaries. Resources, including funding and available water supply, may act as constraints on the amount of habitat creation and enhancement that can take place. Consequently, it will be important to make the best choices among the various options.

Treatments to tributaries can have synergistic effects with activities that seek to improve conditions in the Feather River.

Potential conflicts would likely arise in relation to specific proposals if this measure were implemented. In the Honcut Creek watershed, there may be conflicts with landowners over water supply, water quality and land use controls. On Ruddy Creek, even though there appears to be wide support within the community for a project that would improve aesthetics, there may be conflicts with individual landowners whose property would be altered to allow for a reworking of a stream channel. The location near the Hatchery

would likely have the least conflicts with outside parties because the stream is totally contained within public property, however this measure could conflict with recreational PM&Es proposed for the same area (i.e., conflicting land usage, fishing restrictions or poaching concerns, etc).

There would not appear to be any conflicts between other Resource Actions and this one. However, there is the possibility that implementing this proposal would reduce the amount of resources available for implementing other measures.

Uncertainties:
There are numerous uncertainties associated with creating habitat on the tributaries. These are both general and site-specific. Site-specific constraints and concerns have been discussed previously. Probably the most important general uncertainty is whether or not habitat creation on tributaries will actually improve the productivity of the system.

Cost Estimate:
It is not possible to estimate the costs for implementing this Resource Action. Considering relative costs, the most unreasonable and expensive alternative would be to create and restore habitat in the Honcut Creek system. A project there would also have the highest level of uncertainty. Project costs can generally be ranked as follows: Honcut Creek>Ruddy Creek>Hatchery Channel>Highway 70 Channel.

Creating or restoring habitat on the other tributaries would be much less expensive than a project on Honcut Creek but would nevertheless be costly. Creating channels to connect tributaries to the Feather River would probably cost several hundred thousand dollars per mile of stream. That assumes relatively easy engineering and construction. Instream habitat improvements, such as structure placements and bioengineering would probably cost at least the same per mile of stream.

Recommendations:
There are no easy choices for this Resource Action. The following sequence of further investigations is recommended if this measure is to be carried forward:

For Honcut Creek system:

- Based on information gathered during this field effort, no further investigation of Honcut Creek is warranted.
- An alternative approach to restoration of the Honcut Creek system would be to explore watershed planning through the establishment of a local watershed group. Funding to support watershed planning is available through, for example 319-H grant funding through the State Water Resources Control Board.

For Ruddy Creek:

- No further investigation of anadromous fish habitat in Ruddy Creek is warranted.
- The feasibility of restoring the stream for aesthetic, flood management and wildlife benefits could be considered.
- Decisions about flood management on Ruddy Creek are presently being made for downstream development (a private subdivision is being constructed south of the Afterbay diversion). A combined flood management/stream restoration alternative could be explored. Historically funding for such projects has been available from the DWR Urban Stream Restoration Program.

For the Highway 70 tributary:

- Based on the information gathered during this file study, no further investigation is warranted.

For the Hatchery channel:

- Confirm the availability of water supply.
- Evaluate the feasibility of constructing a downstream connection to the Feather River.
- Further evaluate the apparent continuation of this channel along the terrace to the vicinity of Highway 70.

Resource Action: EWG-104 **Task Force Recommendation Category:** 2

Increase Connectivity of the Lower Feather River to Floodplain Habitats

Date of Field Evaluation: No field evaluation has been conducted.

Evaluation Team: Richard Harris, Koll Buer, and Bruce Ross

Description of Potential Resource Action Measure:
This measure proposes to increase connectivity between the river channel and adjacent floodplain habitats (including low-elevation terraces) in the Feather River below Thermalito. Improved connectivity would be achieved in one or more of the following ways: 1) physical modification of geomorphic surfaces (e.g., reducing floodplain elevations); 2) levee setbacks (e.g., improve access of the river to its floodplain); and/or 3) increasing the magnitude and/or duration of streamflow. This Resource Action replaces EWG-21, EWG-22, EWG-23, EWG-24 and EWG-25.

The following resource actions are directly related to the proposed measure:

- Streamflow Modifications: EWG-4A, EWG-4B (pulsed attraction flows), EWG-100, others aimed at temperature management
- Habitat Enhancement:
    - Rearing and Spawning Habitat: EWG-13A/20
    - Side Channels: EWG-99
    - Channel and Floodplain Modifications: EWG-19A, EWG-93B
    - Riparian Vegetation: EWG-66, EWG-78B (flow regime)

Nexus to Project:
The Oroville project, in conjunction with the existing flood control levee system, has directly contributed to a reduction in the quality and quantity of instream and riparian habitat in the lower Feather River since 1968. Causal mechanisms for this include the trapping of sediment behind the dam, reduced frequency and magnitude of peak flow events and increased summertime flows. In addition to contributing to downstream habitat degradation, the construction of Lake Oroville eliminated potential access to upstream habitat for anadromous salmonids.

Potential Environmental Benefits:
The benefits of increasing connectivity between the river and its floodplain could include improvements in the quality and quantity of fish habitats (i.e., spawning and rearing for splittail and rearing for salmonids) and increased availability of land for recruitment and development of riparian vegetation. Improved riparian vegetation conditions would in turn provide a source of materials for in-stream large woody debris and benefit wildlife that use riparian habitats.

Potential Constraints:
Constraints to implementing this measure would depend on the specific approach taken to improve connectivity of the stream to its floodplain at specific locations. Physical modification of geomorphic surfaces would entail work in and near the channel. This would likely be subject to permitting requirements of the US Army Corps of Engineers, Department of Fish and Game, NOAA-Fisheries, US Fish and Wildlife Service and State or Regional Water Quality Control Board. It would also require at least some engineering design and modeling to determine the proper configuration for the modified surface(s). Levee setbacks potentially would require either willingness by landowners and/or land purchase or must be restricted to current public lands. Approval from the US Army Corps of Engineers and local jurisdictions would also be required. Increasing the frequency or magnitude of peak flow events in order to increase overbank flooding or inundate newly created or re-connected floodplains would be constrained by current operations for flood management and downstream water supply. Increasing peak flows would also require engineering design analysis and modeling to determine potential benefits and impacts.

Existing Conditions in the Proposed Resource Action Implementation Area:
The lower Feather River from Thermalito to the Sacramento confluence has been affected by many land use impacts. Historically, these included hydraulic mining, levee construction, floodplain development for agricultural and urban uses, streamflow diversions and instream construction (e.g., bridges, bank protection, etc.). The Oroville project was superimposed upon an extremely disturbed river. Since construction of the Oroville dam, the lower river has been subjected to an unnatural flow regime and reduced sediment supply. The cumulative effect of all these factors has been a significant reduction in the geomorphic and ecological functions of the river. Indicators of this include a lack of connectivity between the river and its floodplain, significant bank erosion and channel incision, substantially reduced areas of riparian forest, abundance of exotic plants in the residual riparian forest, and impaired habitat for resident and anadromous fishes.

The lower Feather River (especially below Gridley) is presently incised well below its former floodplain (10-25 feet). Studies conducted by DWR indicate that the Rosgen classification for the lower Feather River is “entrenched, F channel type.” Prior to the placement of levees, hydraulic mining, and subsequent downcutting, the lower Feather River was a meandering C channel type, comparable to the Sacramento River and other streams draining to the Central Valley. At intervals of approximately 1-2 years it would have experienced overbank flooding onto its adjacent floodplain. At the present time, only floods in excess of approximately 50,000 cfs would cause flooding out of the entrenched channel. These have occurred about a dozen times over the past 40 years. High magnitude flooding events (>100,000 cfs) have occurred three times, in 1965, 1986 and 1997.

The levee system that protects land adjacent to the river from flooding is not uniformly close to the stream. In some locations, for example, in the developed areas of the cities

of Oroville and Yuba City, levees do completely cut off the stream from its floodplain. In other locations, levees may be absent altogether from one or the other side of the river (e.g., Sutter Bypass). In most places levees are set back over 1,000 feet and agricultural usage is common within the levee boundaries.

The levee system below Thermalito is part of the Sacramento River Flood Protection Project and any proposals to modify the system would have to be approved by the US Army Corps of Engineers and overcome various institutional barriers inherent in maintaining flood protection. If this measure were properly planned and implemented, it could improve flood protection.

The physical constraints preventing the Feather River from accessing its former floodplain are the degree of incision and the currently prescribed flow regime itself that prevents flooding events of magnitudes less than the 100 year flood. Levees are a constraint only in specific places in the lower Feather River, and where they are a constraint, flood hazard considerations may be paramount.

The land ownership below Thermalito is almost exclusively private, although there is some DFG ownership around River Mile (RM) 10 to RM 11. Any proposal to increase floodplain connectivity outside of DFG land would be constrained by the willingness of landowners to either sell their land or allow the Resource Action measure on their land.

With the exception of some reaches (e.g., RM 39 to RM 54 and RM 34 to RM 35.5), within the existing channel between the levees there are relatively few floodplain surfaces. Those that exist are mostly a sandy substrate. The channel bottom itself is typically heavy clay. Consequently, there are not many suitable sites for enhancement of salmonid spawning habitat. Existing information indicates that anadromous salmonids do not typically spawn in the lower Feather River below Gridley (Brad Cavallo, personal communication).

Most existing deposits within the incised river channel are inundated by flows greater than 10,000 cfs. During the summer months flows are relatively high due to water supply releases for downstream uses. For example, under current project operations, median daily flows in August are about 6,000 cfs. It is mostly during the spring runoff season that impaired flows are lower than unimpaired flows (i.e., when the reservoir is filling). Thus, the impaired flow regime does not resemble the unimpaired regime either in timing, magnitude, or duration of peak flows.

Design Considerations and Evaluation:

Of the three potential options previously mentioned (geomorphic modifications, levee setbacks and flow management) different options or combinations of options could be used in different places to achieve the objectives of this measure. For example, under the current regulated flow regime, removing or relocating levees in most locations would not reconnect the stream to its floodplain. It would still be necessary to provide periodic flood flows. That would not be the case, however, in the Oroville Wildlife Area where

levee breaching alone would suffice to reconnect the river and its floodplain. In some other places, existing conditions may be relatively favorable for efforts to restore geomorphic and ecological functions. For example, from RM 39-54, the river still retains high sinuousity, has relatively complex geomorphology and has abundant instream woody debris. There are some existing patches of relatively intact riparian vegetation and levees are well set back from the river. It would be easier to enhance or create instream habitat and floodplain surfaces there than it would be in other locations that are severely constrained by levees. The most difficult places to implement this measure would be those that are deeply incised, severely constrained by levees, and lack geomorphic complexity. If this measure were to be implemented, it would be advisable to select places that already possess some favorable attributes.

The benefits of this measure may be difficult to assess. Some tools, such as PHABSIM, are available for evaluating changes in habitat values due to changes in flow. When both channel geometry and flow are changed, different tools are necessary. The Fluvial 12 model, which is capable of predicting some effects of geomorphic modification and levee removal, has only been calibrated for use from Thermalito to Gridley. Consequently, some other approach, such as US Army Corps of Engineers HEC models would be needed below that point. Again, if places for implementation of this measure are chosen carefully to avoid the need for extensive geomorphic modifications or levee setbacks, some uncertainties can be minimized.

Synergism and Conflicts:
Synergism is achieved by combining geomorphic modifications, levee setbacks, and flow management under one measure aimed at instream fisheries habitat improvement. This measure may conflict with current operations for flood management and water supply. It may also conflict with local landowner and agency objectives unless sites are chosen carefully to avoid conflicts.

Uncertainties:
There are many uncertainties regarding this measure. Some are related to interdependencies between actions such as geomorphic modifications and levee setbacks and requirements for a complementary flow regime. Under the current regulated flow regime, the benefits of these actions could be extremely limited. Other uncertainties pertain to the experimental nature of attempts to improve habitat. The more complex the project, the more potentially uncertain are the results. In situations where other landowners or agencies are involved, their willingness to participate may also be uncertain. The ultimate uncertainty is whether or not the measure would actually improve habitat and the productivity of the fisheries in the lower Feather River. This can only be validated through long term monitoring of fish populations.

Cost Estimate:
It is assumed that this measure will be undertaken in specific locations that will be chosen on the basis of their conditions and expected benefits. Consequently, it is not possible to provide a good estimate of costs. However, some unit costs can be

provided. For example, geomorphic surface modification would require excavation, grading and probably erosion control. Excavation and grading costs are estimated at $12/cubic yard. Erosion control would be in the range of $2,500-$8,000/acre.

Levee setbacks would require land acquisition unless confined to public land (estimated at $2,000/acre), excavation (estimated at $12/cubic yard), reconstruction of the levee (unit costs unknown) and erosion protection/revegetation ($2,500-$8,000/acre).

The costs for providing complementary flow management are equally difficult to estimate. It is assumed that this would consist of providing pulsed high flows at magnitudes capable of inundated reconnected floodplain surfaces. To be effective, these should probably be timed to mimic natural high flow events. Providing such flows would probably be at the expense of power generation or providing water supply to downstream users. Once a flow management strategy is quantified, costs for implementing it could be estimated in terms of lost power or water supply.

Recommendations:

- Further planning for this measure should consider all potential means for improving instream habitats including geomorphic modification, levee setbacks and flow management.
- A process should be developed to select the best sites for implementing this measure. Some criteria for those sites might include:
    - Existing habitat conditions are favorable for enhancement. For example, sites with existing geomorphic surfaces such as side channels and lower floodplains would be good candidates for implementation of a beneficial flow management strategy.
    - Minimal geomorphic changes would be necessary to achieve floodplain connectivity. This is related to the statement above.
    - Lands suitable for enhancement or geomorphic modification are within existing levees. All possibilities for increasing connectivity to floodplains within existing levees should be explored before considering the costly alternative of relocating levees.